# A CONTRIBUTION TO THE STUDY OF INTESTINAL SUTURE, WITH A NEW METHOD OF INTESTINAL UNION.

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IN spite of the various and contradictory reports of experimenters in the field of intestinal surgery, there are three principles generally accepted by almost every surgeon: (1) Serous surfaces must be in contact; (2) if sutures are used, they must include at least a portion of the submucous layer; (3) the most desirable method of intestinal union is one that is safe, can be quickly done by a surgeon of average skill, and that requires no special mechanical appliance. Other points, such as the penetration of all intestinal coats, the use of a continuous or an interrupted suture, are still moot questions, and it will be my endeavor to contribute towards their settlement.

F. G. Connell has very ably championed the cause of the suture that penetrates all the intestinal coats with the knot in the lumen. Samuel D. Gross, in 1843, and W. S. Halsted, in 1887, completely demonstrated that no intestinal suture was safe unless all or a portion of the submucosa was included in its grasp. Halsted advised a suture that would split, but not penetrate, this layer. The impossibility of doing this with any regularity is easily seen when it is recalled that the diameter of a No. 8 sewing-needle—the kind ordinarily used in intestinal work—is six times greater than the thickness of the submucosa in the small intestine, which is about one two-hundred-and-fiftieth of an inch. In the duodenum, as Brunner's glands are in this layer, such a suture, even if it always merely penetrated without perforating the submucosa, would clearly be dangerous.

But, aside from any theory, there are abundant practical proofs of the safety of the through-and-through suture. In Maunsell's operation this principle of penetrating all coats is used, and there have been thirty-one cases operated on with only three deaths. In 1901, Connell reported nineteen cases operated on by his method with only three deaths,—all due to shock and not to a failure of the method. In a paper read before the Mississippi Valley Medical Association in October, 1902 (*American Medicine,* Vol. v, p. 135), he gives a table of sixty-four cases operated upon according to his method by different surgeons. Of this number there were twenty-one deaths, but in only one instance was the operation at fault, all the others dying from shock, previous peritonitis, or some other cause not attributable in any way to the Connell method. So it seems proven that so long as the knots are not exposed on the serosa, an interrupted suture which penetrates all coats is comparatively safe from infecting by capillarity; for, if drainage occurs, it will be towards the cut ends of the thread and, consequently, the knot. The only practical way, then, to obtain a series of sutures that will hold is to have each one penetrate all coats of the intestine.

While there are some enthusiastic advocates of the continuous suture as against the interrupted in intestinal work, the advantages of the former stitch do not seem to be generally appreciated. It has been chiefly urged against this suture that it is not accurate in approximation, and that it is liable to pull loose in one or two places, and so loosen the whole row. These objections are valid when the suture takes up only the serous and muscular coats, for then it cuts or pulls through its bite; but they do not obtain when it penetrates all the coats. I have frequently seen the intestine of cadavers or dogs, when sutured with a through-and-through continuous stitch and subjected to hydrostatic pressure, rupture at a point some distance from the suture line that would still be intact.

It is a surgical axiom that rest is essential for repair. It is this fundamental principle that requires a broken limb to be immobilized, or a pleuritic chest to be strapped. This principle has been utilized in efforts to reduce peristalsis after intes-

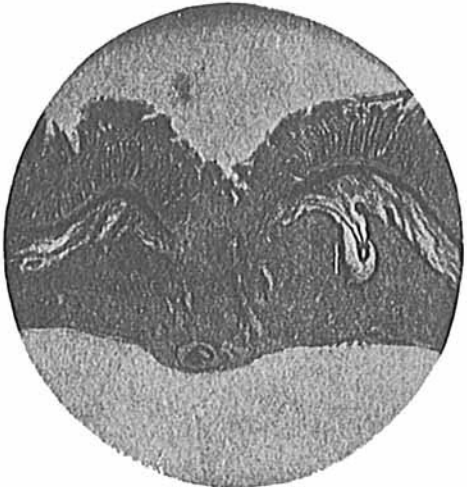


FIG. 1.—Murphy button; thirty-six days. (After J. Henry Barbat, Jour. Am. Med. Ass'n., Vol. xxxiii, p. 126.)

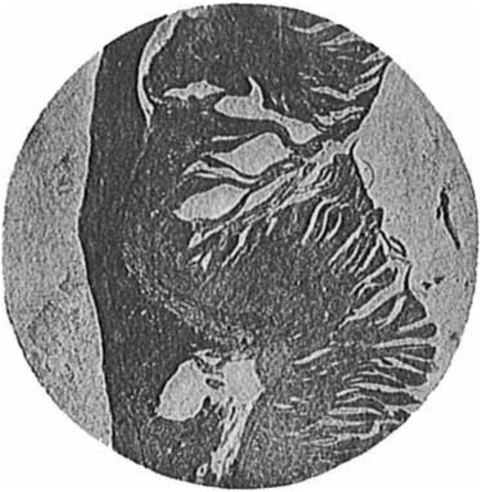


FIG. 2.—Murphy button; fifty-seven days. (After J. Henry Barbat, Jour. Am. Med. Ass'n., Vol. xxxiii, p. 126.)

tinal wounds by giving opium; others, considering gaseous distention of the intestine the greater evil in loosening the stitches, have attempted to relieve this tension with saline purges. In end-to-end union of the bowel it requires but a moment's thought to see what a great advantage the continuous suture, which acts as a splint, has over an interrupted stitch. The portions of the wound between the interrupted stitches are stretched to their utmost when gas accumulates; they are alternately more or less stretched and relaxed with every peristaltic wave. All of this is impossible with a continuous suture through all coats, for, by its splint-like action, it holds the wounded intestinal margins practically immovable and in perfect contact. If distention occurs near the wound, the strain is not put upon the wounded intestine but upon the thread, and the uniform pressure which this suture maintains prevents separation of the wound margin at any point by peristaltic action.

Strictly speaking, there is no such thing as primary union in a wound. In other words, repair of all wounds, whether the healing be aseptic or not, is accomplished by granulation, though it may be so small in amount as to require microscopical demonstration. Even though plastic exudate glues a sutured intestinal wound together in a few hours (F. Mall, *Johns Hopkins Hospital Reports,* Vol. i), firm union must eventually take place by granulation. In a successfully sutured wound this process of granulation is established by the third day, and at this time the line of union is weakest, as demonstrated by hydraulic pressure by von Chlumsky, and confirmed by experiments of my own, mentioned later on. The uniform pressure on the wound margins so necessary at this critical stage is better afforded by the continuous than by the interrupted suture.

Pathologically, an ideal result in an end-to-end union would be a narrow band of approximation, of uniform width, with a minimum amount of scar tissue. It has been clearly shown by Murphy, Barbat, and others that such a result is obtained by the Murphy button (Figs. 1, 2, and 3) and similar appliances when properly and successfully used. How, then, is this obtained? Not by mere *approximation* of serous surfaces, but by *uniform pressure upon these surfaces at every point along the margin of the intestinal wound.* This condition is perfectly filled by the continuous suture that penetrates all coats, but the interrupted suture cannot meet the requirement. Intestinal union obtained by interrupted sutures as ordinarily placed, about one-eighth inch apart, is effected differently at different points of the wound. Within the bite of the suture union is due to pressure of the suture, to the trauma inflicted by the needle, and to the inflammation excited by the presence of a foreign body,—the thread. At a point midway between the sutures, the pressure from the bite of the suture on each side in the thin intestinal tissue is practically *nil;* so union must depend solely upon extension of the inflammation due to the trauma of the needle and the presence of the thread. Such conditions, varying every eighth of an inch, cannot produce an ideal result, and, at least theoretically, may be positively dangerous.

The doctrine, as frequently taught in medical schools, that in intestinal suturing mere approximation of serous surfaces suffices, is misleading. Approximation, unless accompanied by inflammation from pressure, trauma, or the presence of a foreign body, cannot result in union, and, as pointed out above, the closest approximation and the best pathological result are obtained when there is uniform pressure along the entire wound margin. This conclusion was arrived at as the result of the following nine experiments:

Two coils of intestine were laid side by side, as in the operation for intestinal exclusion by lateral anastomosis. A row of continuous stitches from two to four centimetres long was inserted in the long axis of the bowel. At a distance of about one centimetre a second row of sutures, the same length as the first and parallel to it, was placed. The portion of the intestinal wall between these rows was in apposition, but without pressure, except near the region of the sutures.

The dogs were killed on one, two, three, four, six, and eight days after the experiments and the specimens removed, and afterwards examined and measured by a competent pathol-

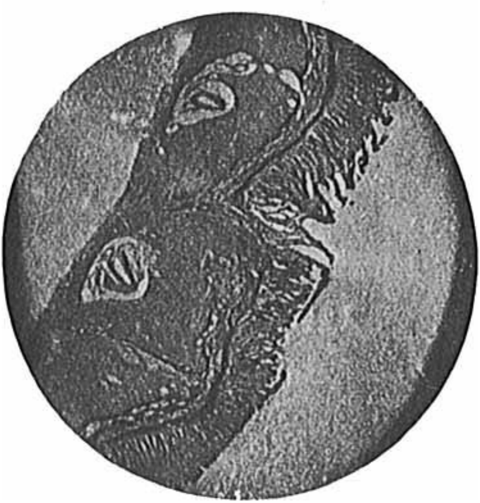


FIG. 3.—Murphy button; sixty-three days. (After J. Henry Barbat, Jour. Am. Med. Ass'n., Vol. xxxiii, p. 126.)

ogist, Dr. J. S. Davis, Professor of Pathology, University of Virginia. In the first six experiments, No. 1 twisted black silk was used; in the last three, No. 2 white braided silk. This was done to determine, in addition, whether the larger size of the latter suture material would markedly cause more inflammation and exudate.

In these nine experiments, out of the first series of six, in which small black silk was used, in only two experiments did all the area included between the rows of sutures unite. Of the three experiments in which No. 2 braided silk was used, in only one instance all of the area included between the rows failed to unite. This indicates clearly that approximation alone is not sufficient to secure accurate results in every case of intestinal suture. In these nine experiments an area of intestine was thoroughly approximated, and held in this condition by the splint-like action of the continuous suture. In only four did all of the area included between these rows of sutures unite. The report of the pathologist also shows that more reaction, inflammation, and resulting adhesions occurred when a coarse silk suture was used. This is borne out by the fact that in the last series of three experiments, in which the coarse silk was used, the inflammation excited was sufficient to cause adhesion of all the area included between the sutures in two of these experiments.

## A NEW METHOD OF INTESTINAL UNION BY SUTURE.

Before proceeding to the technique of the operation, it may be well to give some observations that have accumulated as the result of a moderately extensive experience in experimental intestinal surgery, both on the lower animals and the cadaver. I may preface these remarks by repeating what I have already alluded to, that, so far as the pathology of the line of union is concerned, the successful cases following the proper application of a well-constructed Murphy button or similar contrivance give an ideal result. However, as is well known, all Murphy buttons are not properly constructed nor properly applied, and, even when these conditions are complied with, occasionally the button is retained or perforation occurs. It is generally recognized that any operation dependent upon a specially constructed mechanical device is handicapped; and it is equally true that a large foreign body left fixed in the intestinal canal may be a source of danger.

In the application of intestinal sutures, I have used a No. 7 or No. 8 ordinary sewing-needle and have found them entirely satisfactory. I have also made constant use of the thimble. Albert found the thimble of decided advantage in intestinal suturing, and it seems strange that it is so little used. It is awkward at first, but a little constant practice in ordinary sewing readily overcomes this. The thimble is considered indispensable by the most expert needle-women, and surely it must have some advantage in placing delicate intestinal sutures.

The suture material ordinarily used in this work is fine, black, twisted silk, usually No. 1. This has several disadvantages, particularly in intra-intestinal suturing. It does not fill the needle puncture completely. Though from its natural elasticity the submucosa tends to diminish the size of this puncture, still, it would be safer to have a thread that would completely block it and prevent all possibility of leakage. Fine silk cuts, and so may enlarge the puncture, and for this reason, aside from its tensile strength, cannot have as firm a hold as a larger thread. Twisted silk is liable to tangle. My experience has been that the best results are obtained by using braided silk of the largest size that can be gotten through a No. 7 or No. 8 needle. This is No. 2 braided silk, and has great tensile strength, fills the needle hole completely, does not cut out, and does not easily tangle. While this is particularly applicable to sutures that penetrate all the intestinal coats, it is also partly true of stitches of the Lembert type.

There is a great deal of difference of opinion in regard to what should be the name of the operation by which a breach in the continuity of the intestinal canal is repaired, when such repair is done by an end-to-end method. The term "anastomosis," as has been pointed out by Senn and others, is certainly not appropriate in this connection. Its use implies the formation of some indirect opening to compensate for obstruction in the main channel. Hence, the removal of such obstruction and the re-establishment of the former channel cannot properly be called an "anastomosis." Circular enterorraphy is equally objectionable. Enterorraphy means simply that the intestine is sutured, so there would have to be another term to designate end-to-end union of the intestine by mechanical appliances, such as Murphy's button. Besides, circular enterorraphy implies merely suture of the intestine in a circular manner. In the operation for prolapse of the rectum, in which the sigmoid flexure is sutured to the abdominal wall, if such sutures are inserted in a circular direction, "circular enterorraphy" could certainly be applied to this procedure. The term end-to-end union of the intestine seems to be free from the objections just mentioned, and is used in this paper.

The operation as originally conceived appeared first in the *New York Polyclinic,* December, 1897. After this preliminary report was published, further experimental work done on eleven more dogs showed that it was difficult to invaginate the mucosa with an overhand stitch, and also that the outer row of sutures was unnecessary, and in experimental work, at least, positively dangerous. In four of these eleven experiments, the outer row caused such a large diaphragm to be turned in that death resulted from obstruction.

The technique as now recommended and performed successfully on nineteen dogs is as follows: The intestinal clamps are placed, or a single knot of a soft rubber tube used, as recommended by Ballance and Edmunds, to obtain coprostasis. The mesentery is incised; in resection, a triangular portion may be removed. The vessels at the mesenteric border of the intestine are clamped before being cut. The forceps that clamp the vessels are also made to include both layers of peritoneum as they separate from the mesentery to encircle the bowel. The tissue within the bite of the forceps is ligated with fine silk, so drawing the peritoneum over the area of bowel usually devoid of a serous coat, and at the same time closing the vessels. This stage is shown in Fig. 4. Next, the bowel is divided, or re-

FIG. 4.

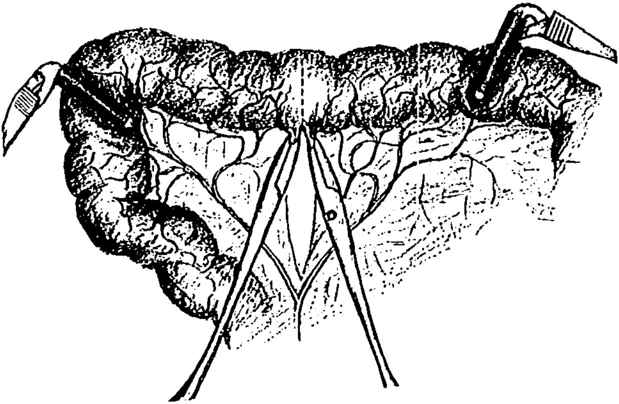
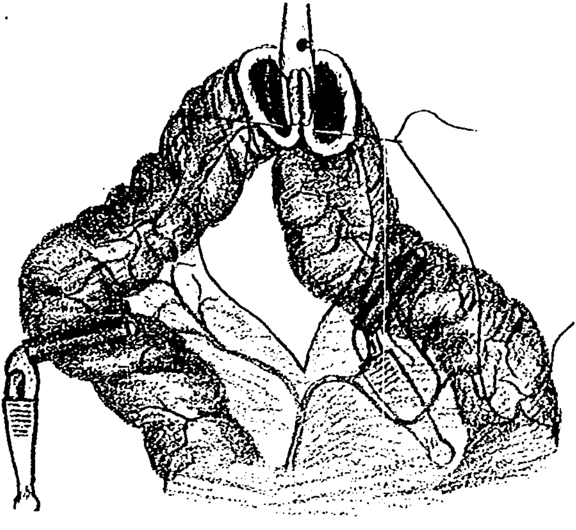


FIG. 5.



sected, as the case may be, and the convex borders placed in contact and held in this position with a hæmostatic forceps. An ordinary No. 8 sewing-needle threaded with No. 2 braided silk transfixes both walls of the intestinal ends about half-way between the mesenteric insertion and the forceps (Fig. 5). The suture is drawn through and tied. A portion of the intestinal walls forming a crescentic area, the centre of which is grasped by the hæmostatic forceps, is now cut out with scissors, by cutting about one-third of an inch at a time and suturing the cut edges together with a continuous circular (overhand) stitch, penetrating all coats, then cutting another one-third inch and suturing, and so on until the crescentic area is excised (Fig. 6).* The needle is inserted about eight times to the inch, and moderately firm tension is constantly kept on the thread with the left hand. When this crescentic area has been removed, and the margins from which it was cut have been sutured in the manner described, the needle is thrust directly through the intestinal wall just to the right of its last puncture and emerges from the serosa. The character of the stitch is now changed to a Cushing right-angled continuous suture, penetrating all coats, and readily inverts the remaining margins of the wound (Fig. 7). This stitch is continued (Fig. 8), with moderately firm traction on the thread. When the first knot is reached, it is invaginated, and the suture continued by two more insertions of the needle. With these last two insertions of the needle as secure a hold as possible is obtained without penetrating to the mucosa. The very last insertion of the needle is in the reverse direction of the other insertions, so that when the knot is tied it is partly buried (Fig. 9). If desired, it may be completely buried by a Halsted stitch, though I have never thought this necessary. After this suturing is completed, scarcely any of the thread can be seen, except a portion of the knot, unless the bowel ends are pulled upon. The bowel is then turned to its natural position, and with another needle similarly

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* Or the continuous Connell suture may be used, suturing first for a few stitches and then cutting.

FIG. 6.

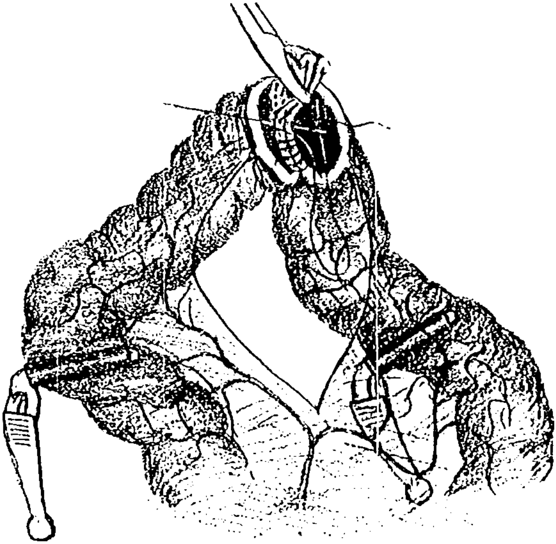


FIG. 7.

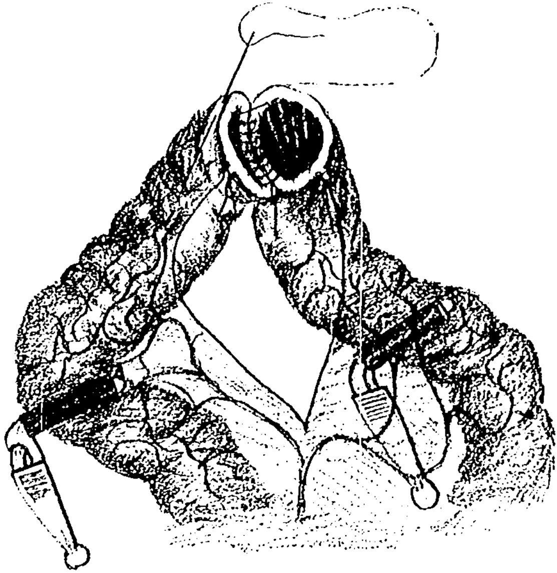


FIG. 8.

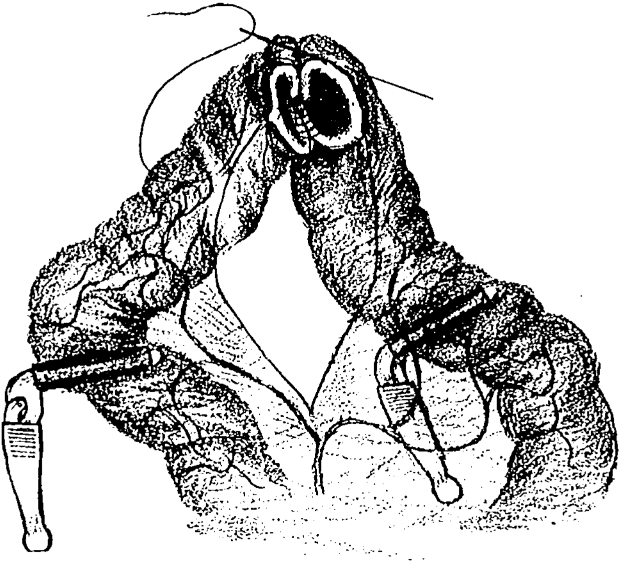
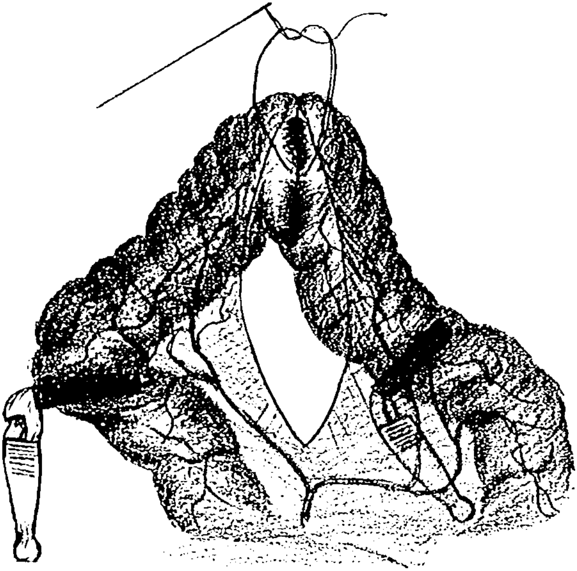


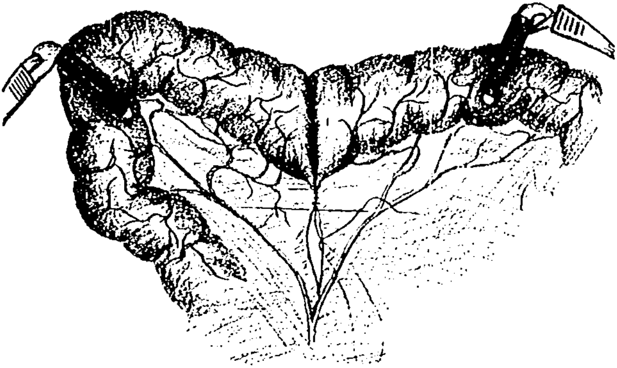
FIG. 9.



threaded the mesentery is sewed up with a continuous stitch (Fig. 10). The needle is inserted in the mesentery at its junction with the bowel, and the first knot when tied acts as a mesenteric stitch. It is placed close to the bowel, though no attempt is made to include any portion of the intestinal wall in its grasp, as in the Mitchell, Heamner or Halsted mesenteric stitch.

Nineteen dogs were operated on by this method without a death.

FIG. 10.



In the few instances in which an insufficient lumen or too many adhesions resulted, the cause of the former fault can always be attributed to the placing of an extra row of reinforcing sutures or to invaginating too much intestine at the mesenteric border. I feel quite certain that both of these things were frequently done unnecessarily. However, the results of these experiments, both as to lumen and as to adhesions,—upon which Halsted lays so much stress,—can be favorably compared with those of experiments from any other method of intestinal union. This method has many advantages.

First of all, it is efficient, as demonstrated by nineteen consecutive operations on dogs by this technique without a death, and by the manner in which it has resisted hydrostatic pressure in specimens both from dogs and cadavers.

It requires no complicated apparatus or special mechanical device for its performance. A thumb forceps, two hæmostatic forceps, a pair of scissors, needle, thread, and thimble are all the instruments needed. In fact, the hæmostatic forceps can be readily dispensed with, for the first two ligatures can be applied with needle and thread, and through the crescentic area to be excised a thread can be passed with a large needle, firmly tied, and used as a guy-thread in place of the forceps while cutting out this crescentic area. So all that is absolutely necessary to perform this operation is a pair of scissors and needle and thread. As intestinal union is pre-eminently an emergency operation, this fact should be decidedly in its favor.

Though W. A. Evans has demonstrated that the danger from stricture following intestinal resection is greatly overrated, still, it cannot be entirely eliminated, for some well-authenticated cases are on record. At any rate, diaphragm formation is a real danger, at least in experimental work, as is well demonstrated by four deaths in one of my series of experiments. Post-mortem showed each death to have been caused by obstruction from inverting too much intestine. Another dog died from the same cause on which a Halsted end-to-end union had been performed. All of the end-to-end methods in which serous coats are apposed must have some diaphragm formation, for the principle of approximating serosa to serosa necessarily implies inversion of a portion of the intestinal wall. The diaphragm may be very slight, as Ballance and Edmunds state in the case of Maunsell's operation, or extensive, as when two or more rows of sutures on the Lembert principle are used. However, it cannot be claimed that a diminution of the intestinal caliber at the point of suture is a desirable thing, even though such a diminution be slight. It must be borne in mind that this means increased pressure and friction at the point of union; and, if the sutures are not pulled out or their hold injured thereby, there is always a future possibility of ulceration or even malignant invasion at this point, unless the diaphragm turned in atrophies, or unless the stitches loosen and the intestine straightens out, which F. Mall says occurs about the fourth week. This change, however, does not always occur, as is demonstrated by a photomicrograph of J. Henry Barbat (*Journal American Medical Association,* Vol. xxxiii, p. 128), showing a diaphragm, without any attempt at straightening of the intestine, ninety-nine days after a suture operation (Fig. 11). It seems unlikely that a diaphragm which has existed for this length of time, and in which union has become firm and well organized, will ever straighten out in the manner indicated by Mall. In my operation, owing to the excision of the crescentic area, the diameter of the intestine at the point of union is always greater than its normal diameter.

I have attempted to demonstrate elsewhere in this paper that the continuous suture penetrating all intestinal coats is the best. In the operation described this suture is used, and it is unnecessary to repeat here the arguments in its favor, though I may add that it controls bleeding, sometimes a point of no little consequence. It has been objected that this suture, while working into the lumen of the bowel, may hang partly attached for weeks before being cast off, and during this period prove a source of obstruction. In a number of experiments, after observing the suture in all stages, I have never seen it act in this manner, nor has any one else, so far as I can learn. I have never seen any accumulation of fæcal matter with the suture as nucleus; and if this does not happen in dogs with coarse diet and intestines of small caliber, it surely should not occur clinically. The objection is purely a theoretical one, not borne out by experimental or clinical evidence.

This operation can be very quickly performed, and ordinarily takes but little, if any, longer than the application of a Murphy button. I have performed it in eight minutes, and can do it in from twelve to fourteen minutes without any undue haste.

Finally, the technique is quite simple and, unlike the Connell and some other methods, is easy to learn and difficult to forget.

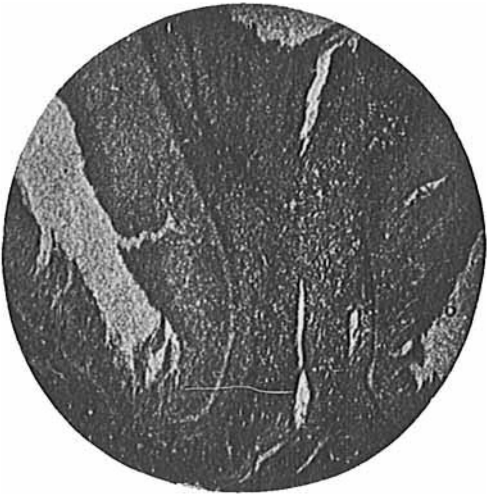


FIG. 11.—Suture, ninety-nine days. Showing result usually obtained by suture. (After J. Henry Barbat.)

## TESTS OF DIFFERENT METHODS OF INTESTINAL UNION BY SUTURE.

In the experimental work of von Chlumsky along this line (*Centralblatt für Chirurgie,* 1899, Vol. ii, pp. 33-37), suturing was done according to the method followed for many years in Mikulicz's clinic, which corresponds essentially to Albert's double suture, employing continuous sutures. In addition, in other cases, the buttons devised by Murphy, Frank, and other surgeons were employed, the author's description being exactly followed.

At first, the strength of the intestinal union was tested by means of direct mechanic traction at one end of the bowel-loop and the fastening of weights to the other end. These experiments were inexact and unsatisfactory.

Much more exact, however, were the results of those experiments in which was ascertained the amount of pressure which the union could stand without breakage. These tests could be easily made and the pressure conveniently measured; in addition, the results were more satisfactory, as the least leakage was readily recognized by the escape of the fluid. Of course, even this method is not entirely free from criticism, and cannot be used in the human subject. The same operations were performed on fresh human cadavers and upon dogs for purposes of comparison.

The result of von Chlumsky's experiments showed that an intestinal union was weakest in the third and fourth days after operation, being comparatively strong after twenty-four hours.

In working on the experiments to be described, I have used a technique somewhat different from that of von Chlumsky. It was my endeavor to select two typical methods of end-to-end intestinal union by suture, and to test these as representing practically all classes of end-to-end union by suture, except those in which invagination forms an essential part, as in the operations of Morisani, Kelly, Harris, and Moreau. As a type of sutures of the Lembert class, the Halsted end-to-end method was taken. The method of F. G. Connell was selected as representing the class of operations in which all coats are penetrated and the knots tied within the lumen. The operation above described was compared with these two types.

These operations were performed on dogs, and, wherever possible, all three were done on the same dog at the same time, so that the idiosyncrasies of the individual dogs, constitutional difference in resistance, etc., might be eliminated as far as possible. Whether the operations to be tested at the expiration of the same time were performed on the same dog or not, in all instances dogs of about equal weight were chosen, and conditions made to be identical so far as possible. Only those dogs in which the operation was successful, and in which general peritonitis did not result, were used in making the tests. The tests were made by water. It was observed that a pressure of eleven feet of water always ruptured the muscular and peritoneal coats if it was maintained for four minutes. This was taken as the maximum, and when a union would stand a pressure of eleven feet of water for four minutes without leaking, the result is recorded as eleven feet plus. About six inches of intestine were removed in each experiment, the site of operation occupying the middle of this section. One end was closed with a clamp, and into the other end was securely tied the nozzle of an irrigator filled with colored water. The intestine was gradually lowered about six inches at a time, and kept in this position for one-fourth of a minute. If leakage did not occur, it was lowered six inches more, and so on until the maximum of eleven feet was obtained, unless leakage occurred before this point was reached. In the latter case, the distance from the point at which leakage occurred to the level of the water in the irrigator was measured and recorded as the pressure which this particular operation bore.

EXPERIMENT I.—Black, short-haired, mongrel, male dog, medium weight. Connell operation, interrupted sutures. This operation was found rather difficult in the dog, being considerably harder to perform than on the cadaver, on account of the thickness of intestinal wall and eversion of the mucosa, which makes approximation more difficult, particularly in tying the last knot. Halsted mattress suture end-to-end method was also performed on this dog. Specimens removed after twenty-four hours showed the lumen in the case of the Halsted operation almost obliterated. No peritonitis or leakage from either operation. By hydrostatic pressure, it was impossible to rupture the Connell method with eleven feet of water. The Halsted method leaked at five and one-half feet.

Experiment 2.—Short-haired, black and white, mongrel, male dog, medium weight. The new operation performed. Time, fourteen minutes. Specimen removed after twenty-four hours. Some omental adhesions to suture line. Leakage occurred at five and one-half feet of hydrostatic pressure.

Experiment 3.—Heavy-set, black, male dog, medium weight. Connell and Halsted methods performed as in Experiment 1. The new operation also performed, taking only eight minutes. Specimens removed after two days (forty-eight hours). Connell method, eleven feet plus; Halsted method, three feet; new method, five and one-half feet.

Experiment 4.—Long-haired, black bitch, medium size. Connell and Halsted methods as in previous experiment. New operation also performed. Time for latter, nine minutes. Dog died after two days from general peritonitis, from leakage at the last stitch in the Connell operation. The other two methods showed no leakage.

Experiment 5.—Liver and white, setter, male dog, medium size. Connell and Halsted methods as in preceding experiment, and new method. Time for latter, twelve minutes. Specimens removed after three days, all of them in good condition. Connell method leaked at three feet, Halsted at three feet, and new method at three feet.

Experiment 6.—Long-haired, brindle and white, male dog, medium size. Connell, Halsted, and new methods as in preceding experiment. Time for the latter, twelve minutes. Dog died after thirty-six hours of general peritonitis, from leakage at a point in the suture line of the Connell method. In this instance it was my fault and not a fault of the method, as several of the stitches were tied unduly tight. The other two operations showed no leakage.

Experiment 7.—Shepherd male dog, medium size. Connell, Halsted, and new operation performed as in preceding experiment. Time for latter, twelve minutes. Specimen removed after four days. Connell method leaked at ten and one-half feet, Halsted at five feet, new method at ten feet.

Experiment 8.—Long-bodied, long-haired, black, male dog, medium size. Connell, Halsted, and new operation as in preceding experiments. Time for latter, fifteen minutes. Specimens removed after six days. Connell method, eleven feet plus; Halsted, eleven feet plus. New method leaked at eleven feet.

Experiment 9.—Heavy-set, yellow cur, male dog, medium size. Connell, Halsted, and new operation performed as in preceding experiments. Time for latter, thirteen minutes. Specimens removed after eight days. Connell method, eleven feet plus; Halsted, eleven feet plus; new method, eleven feet plus.

The results of these experiments clearly indicate that a suture through all coats of the intestine is stronger during the first six days than a suture that attempts to include merely a portion of the submucosa. While the Connell method stands more pressure at the end of the first and the sixth day, the new method stands practically as much pressure as the Connell operation during the critical time in intestinal union, which is the third and the fourth day.